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A Study on Pore-forming Agent in the Resin Bond Diamond Wheel Used for Silicon Wafer Back-grinding

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Abstract

Thinner thickness of the subsurface damage (SSD) layer and lower surface roughness of the grinded silicon wafers should be required, which would depend on high self-sharpening ability and consistent performance of the resin bond diamond wheel used in back-grinding. In this paper application of the pore-forming agent for improving these properties of the grinding wheel was experimentally studied. The bonding strength and the grinding performance of the resin-bond diamond wheel affected by the pore-forming agent were evaluated by testing.

Keywords: Silicon wafers; back-grinding; resin-bond diamond wheel; pore-forming agent

1. Introduction

The monocrystal silicon wafers have several excellent characteristics such as high purity, high precision and high surface quality, which have been playing an important role in development of the integrated circuit (IC) industry. More than 90% of ICs across the world are made by monocrystal silicon wafers [1].

Diamond wheel grinding can be applied to the planarization of both original and etched silicon wafers for the purpose of improving the flatness of silicon wafers, thus reducing the removal amount of silicon wafers for the next polishing procedure. The other application of diamond wheel grinding includes reducing the thickness of the silicon wafer before scribing into silicon chips [2].

The diagram of wafer back grinding technology using a cup-shaped diamond grinding wheel is shown

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in Fig. 1. During the grinding, the wheel and the wafer rotate around their own axial lines simultaneously and the wheel feeds the wafer along its own axial line.

The thickness of subsurface damage (SSD) layer and surface average roughness values of the silicon wafers after ground are important indicators to evaluate the grinding quality [3]. To obtain low thickness of SSD layer and surface roughness, the grinding wheel should have consistent grinding performance during the grinding process. That is to say, in the life cycle of grinding wheel, the difference of grinding performances of the working layers with different thicknesses have to be very small, the grinding force has to keep consistent (this can be indicated by the grinding machine's power. When the voltage is invariable, the current change is the grinding force's change), and any fluctuation of the grinding force will cause the change of the surface quality of the silicon wafer. Fig. 2 shows an example of fluctuation of the grinding force (It is reflected by the current fluctuation in the grinding process). The test is conducted in Wuxi Huajing Microelectronics Co., Ltd. The inflection point position * marks a passive dress is added.

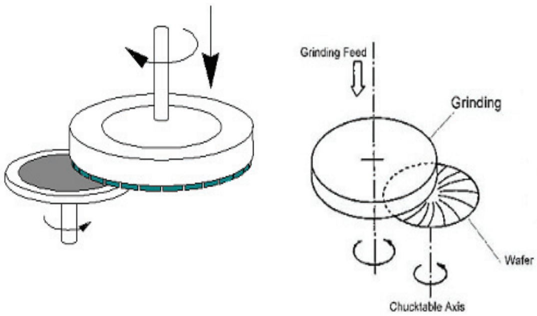

Fig. 1. The schematic diagram of wafer backgrinding.

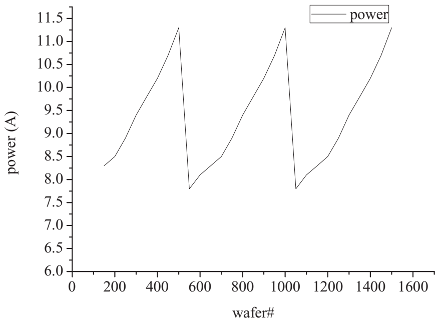

Fig. 2. Example of current fluctuation in the grinding process.

The consistency of the grinding wheel requires the grinding wheel to have a good self-sharpening ability. That is to say, the grinding wheel is not permitted to conduct any intermittent trimming after its first dressing. However, Fig. 2 shows that the wheel grinding force increases continuously until it reaches a limit, after which one passive trimming has to be conducted, if not, scratches and even breakage of wafers may appear. Therefore, the self-sharpening ability of the grinding wheel needs to be improved.

To improve the self-sharpening ability of the grinding wheels, TANAKA et al [4] developed the multi-pore ceramic-bond grinding wheel made with ultrafine diamond micro power (～0.125μm). The pores are made by volatilizing the pore-forming agent added to the ceramic-bond. RAMANATH et al [5] invented resin-bond diamond grinding wheels with high-concentration pores for grinding silicon wafer and the average size range of diamond grains was 0.5-70 μm. Matsumoto et al etc. [6] invented a kind of resin-bond diamond grinding wheel containing high-concentration pores for grinding silicon wafer, the filling materials in cavities were silicon and miniature balls, whose diameters were greater than those of diamond grains. ITOH [7] invented a kind of ceramic-bond grinding wheel strengthened by injecting artificial resin and surfactant, and their structure was provided with the retiform cavities filled with hot setting resin. However, there are few reports on the characteristics of pore-forming agent and grinding performance data of diamond grinding wheels made with. This paper will introduce our studies and research results on pore-forming agent for improving the self-sharpening ability of the resin-bond diamond grinding wheels used for silicon wafer grinding.

2. Experimental

2.1 Main materials

Resin-bond diamond (2000#, 4-6 μm grain size) grinding wheel and 6-inch monocrystal silicon wafers were used for the test. The basic features of the four types of pore-forming agent A, B, C and D are shown in Table 1.

Table 1. Basic features of pore-forming agents.

Pore-forming agent Type	Mode	Category	Density(g/cm^3)
A	Micro-spherical	Polymer	0.3
B	Grainy	Methyl amine	1.76
C	Powdery	Aromatic Benzene aromatic hydrocarbon	0.8
D	Powdered	Natural macromolecule	1.25

2.2. Main instruments and equipments

QUESTAR microscope KH-7700. Universal electronic tensile testing machine XJ828. Hot press machine MYS-200T. Ultra-precision silicon wafer grinding machine DFG8540 manufactured by Disco Corporation of Japan. 5022-type 3D surface profilometer ZYGO Newview, manufactured by ZYGOLamda Measuring Equipment (Shanghai) Co., Ltd. Portable surface roughness detector TR200, manufactured by Beijing Times Group Co., Ltd. Desktop single-sided grinding machine EJ-380IN， manufactured by Kingtech Grinding Technology (Shanghai) Co., Ltd.

2.3. Testing of grinding performances

The grinding wheel samples were prepared by hot pressing at Hot Press Machine MYS-200T. The pore-shaping states of pore-forming agent were shooting with QUESTAR microscope KH-7700. The mechanical strength of the bond with different amount of pore-forming agent was measured on the universal electronic tensile testing machine. The wheel's grinding power was measured on ultra-precision silicon wafer grinding machine DFG8540, by recording the power display value of the wheel spindle during the test and averaging the recorded values of the current during the grinding process. When conducting routine production line tests, the portable surface roughness detector TR200 is adopted, while conducting random tests, 5022-type 3D surface profilometer ZYGO Newvie was adopted to measure the roughness of the ground silicon wafer. The damaged ground surface depth of the silicon wafer was measured by the angle polishing approach. The wear rate of the wheel was recorded by every 100- wafer being ground. Through the calculated wear rate of the grinding wheels we can get to know their working life characteristics. All the detection results were averages taken from the data in measuring the grinding silicon wafer test specimens for 9 times.

3. Results and Discussion

3.1. Grinding performances of the wheels

The performance of the grinding wheels added with pore-forming agent was investigated and the results are shown in Table 2 and Table 3.

Table 2. Comparison of the performance data of grinding wheels.

Grinding wheel type (Pore-forming agent)	Current of principal axis (A, max)	Thickness of damage layer (μm)
A#	11.3	3.5
B#	8.5	0.92

Table 3. Comparison of the performance data of grinding wheels.

Grinding wheel type (Pore-forming agent)	Average roughness of silicon wafers (Ra nm)	Wear of grinding wheels(μm/slice)
A#	8.580	0.26-0.32
B#	6.715	0.4-0.45

All the tested grinding wheels with added pore-forming agent can grind the silicon wafers smoothly. The surface of the ground silicon wafer is shown in Fig. 3.

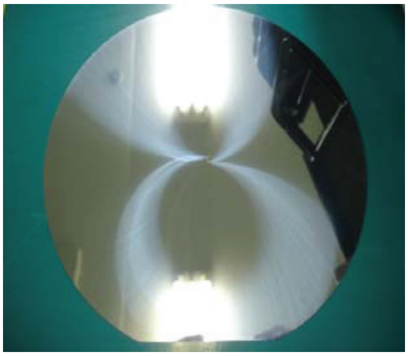

Fig.3. Photo of the ground silicon wafer (surface roughness Ra= 9.76nm).

3.2. Influence of the added pore-forming agent amount on the bond strength

The test results of mechanical strength were shown in Fig. 4. The flexural strength of the wheel samples added with 15% volume fraction (V/V) of pore-forming agent is higher by 100% than that of the one added with 50% pore-forming agent. The flexural strength of the wheel samples added with 15% pore-forming agent was only reduced by 9% compared with that with no any additive. High speed rotary test results showed that the strength of the wheel sample added with 15% pore-forming agent can well met the requirement of the safety rotation speed for the back grinding wheel.

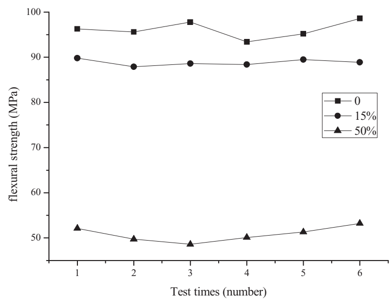

Fig. 4. The influence of the added pore-forming agent amount on the bond strength.

3.3. Influence of the pore-forming agent on the self-sharpening ability of grinding wheel

The recorded current values during the grinding test prove that, the other advantage of the wheel samples with increased pore rate can improve its self-trimming ability, as shown in Fig.5.

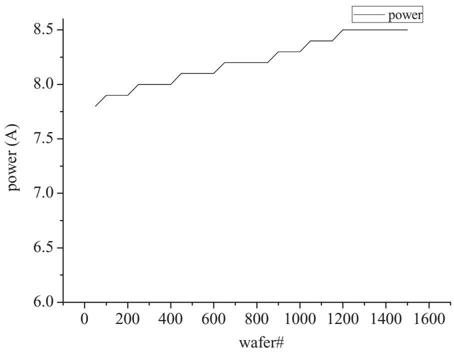

Fig.5. Example of a grinding course with constant current.

The grinding wheels with improved self-sharpening ability by adding pore-forming agent are supplied to Wuxi Huajing Microelectronics Co., Ltd. The application results proved that, the wheels need no passive dressing and the current is fundamentally stable below 8.5A, which means that during the grinding process the grinding wheel has good self-sharpening ability.

3.4. Influence of the pore-forming agent on the SSD and surface roughness of the ground silicon wafer

Comparing with the width of black area in Fig. 6, it is seen that when the added amount of pore-forming agent increases from 5% to 15%, the thickness value of SSD layer for the ground wafer decreased from 3.2 µm to 0.92 µm.

Comparing with the surface quality of the ground wafers in Fig. 7, it is shown that when the addition amount of pore-forming agent increases from 5% to 15%, the surface roughness of ground silicon wafers would reduce.

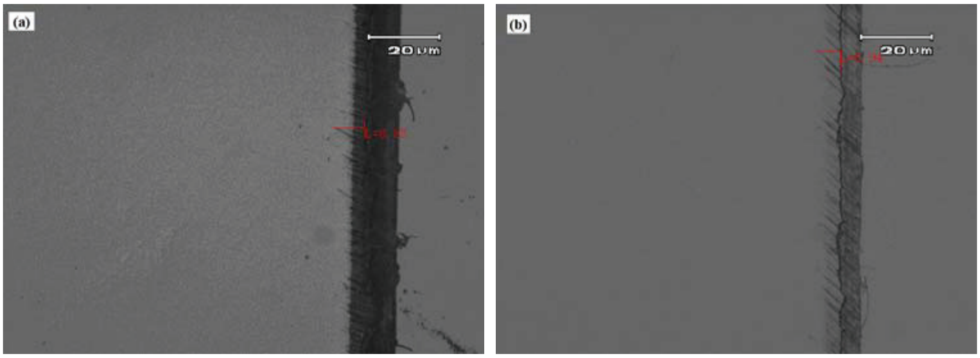

Fig. 6. The cross profile features of the ground wafers added different amounts of pore-forming agent: (a) 5% (SSD value = 3.2 µm); (b) 15% (SSD value = 0.92 µm).

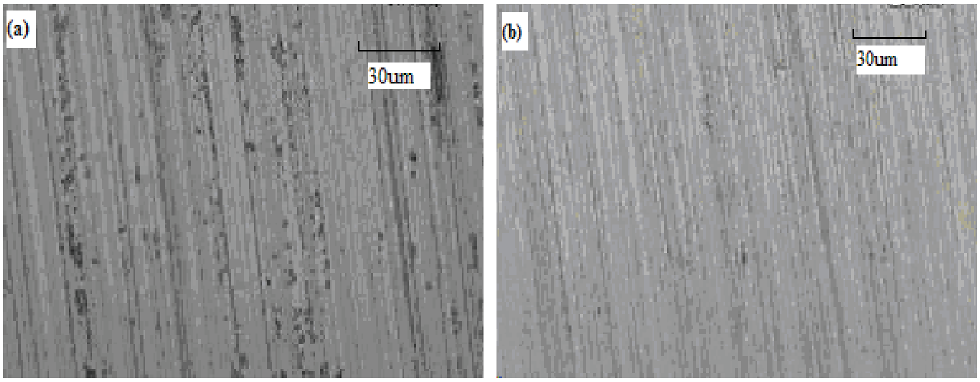

Fig. 7. The surfaces of the ground wafers added different amounts of pore-forming agent: (a) 5% (R_a = 8.580 nm); (b) 15% (R_a = 6.715 nm).

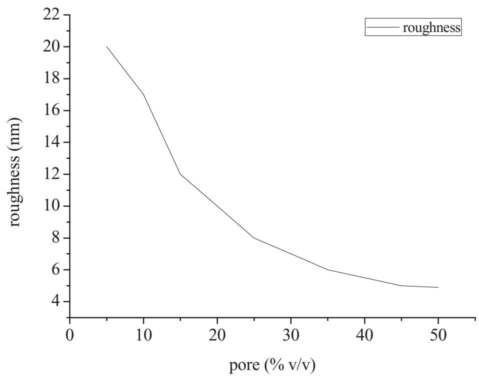

Fig. 8. Influence of the pore amount on the surface roughness of the ground silicon wafer.

Influences of addition amounts of the pore-forming agent on the ground surface roughness of the silicon wafer are shown in Fig. 8. It is found that, along with the pore ratio of the grinding wheel increases, the surface roughness of the ground silicon wafer reduces. While the pore ratio of the grinding wheel increases, the wheel wear rate increases slightly. The wheel working life is examined by grinding 6-inch silicon wafers. The results showed that, when the machining allowance is 20 μm, the wear rate of the wheel increases from 0.26-0.32 μm/slice to 0.4-0.45 μm/slice, when the pore ratio of the grinding wheel increases. When addition amounts of the pore-forming agent were increased from 5% to 15%, the roughness value R_a would decrease from 8.580 nm to 6.715 nm.

4. Conclusions

Adding pore-forming agent can improve the self-sharpening ability of the wheel when ground silicon wafers. Four different kinds of pore-forming agent were added to the back-grinding wheels. The gas foaming pore-forming agent resulted in better grinding effect. The types and added amount of pore-forming agent have important influence on the bond strength. The excellent grinding performance of the wheel can be achieved by adding 15% (in volume) pore-forming agent, and the average bond strength of the grinding wheel only reduces by 9%, while the self-sharpening ability was obviously improved. After grinding, the average subsurface damaged layer thickness of the silicon wafer would reduce from 3.5 μm to 0.92 μm, and the roughness value R_a would decrease from 8.580 nm to 6.715 nm, when addition amounts of the pore-forming agent were increased from 5% to 15%.

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